THE JOURNAL OF THE CANADIAN ASSOCIATION OF RADIOLOGISTS

Editorial Board

Chairman: ORIGENE DUFRESNE, M.D.
L. P. BELISLE, M.D.
NORMAN M. BROWN, M.D.
J. S. DUNBAR, M.D.
D. L. McRAE, M.D.

Associate Editors

H. E. JOHNS, M.D.
G. I. NORTON, M.D.
G. PINSONNEAULT, M.D.
T. A. WATSON, M.D.
D. G. WOLLIN, M.D.

Volume VI | September 1955 | Number 3

CONTENTS

	Page
Editorial	viii
Calibration of Cobalt Units Using Radium as a Standard — *C. Garrett and W. H. Henry*	35
Calibration of Cobalt-60 Using Absolute Ionization Measurements — *H. E. Johns, D. V. Cormack and G. F. Whitmore*	37
Calculation of Absorbed Dose in the Patient from the Measured Exposure in Air — *G. N. Whyte*	39
Cancer of the Lip — *T. A. Watson and C. C. Burkell*	41
Foetal Achondroplasia — *H. P. Kent*	47
Association Notes:	
Awards in Radiological Research	46

QUARTERLY

Subscription: $2.00 per annum

Publication Manager—Gwendolyn A. Mollison

Medical Secretarial Service Reg'd.

Suite 305, 1555 Summerhill Avenue — Montreal 25, Quebec, Canada.

EDITORIAL

CALIBRATION OF COBALT-60 UNITS IN CANADA

In the last three years nine cobalt-60 teletherapy units have been installed in clinics in various parts of Canada. The radiotherapist and physicist now have a source of radiation whose output is known with precision as a function of time once the output is determined accurately at a particular time. Such a radiation machine offers a continued check on the standardization of dosemeters. For this reason, and in order to be able to estimate the dose delivered to a patient during treatment, the absolute measurement of cobalt-60 gamma radiation has become important.

The instrument most commonly used for the measurement of x-ray and gamma-ray outputs is the Victoreen condenser r-meter. However, a number of problems arise in the use of these chambers for cobalt-60 measurements.

(1) The wall thickness must be increased to about 0.4 gm/cm^2 in order to yield electron equilibrium. This can easily be achieved by placing an additional cap of lucite over the regular Victoreen thimble.

(2) A second difficulty arises from leakage in the insulator and small air gaps of the stem of the chamber. If the whole of the condenser chamber is irradiated, this leakage may amount to several percent of the required reading.

(3) The Victoreen chamber cannot readily be calibrated with a standard air chamber at cobalt-60 energies since the standard air chambers now in use are designed to operate only up to about 250 KV. It has been found that a Victoreen chamber that has been calibrated to read correctly at 200 KV does not read correctly at cobalt energies. The difference in response is presumably due to the small amounts of material of atomic number higher than air that are incorporated into the wall and inner electrode of the chamber in order to flatten its response over the conventional region of x-ray energies. The effect of this material is to increase the response of the chamber in this energy region over what it would be for an "air-wall" chamber of the same volume, with the result that at higher energies (where the photoelectric effect becomes unimportant) the response is low. The national standardizing laboratories find that when Victoreen chambers have been calibrated at around 200 KV, their readings at cobalt energies must be multiplied by factors ranging from roughly 1.05 to 1.15, depending on the individual chamber.

The calibration of such a chamber may be checked by using a standard source of radium and adopting an output of 8.4 r/hr at 1 cm from a 1 mgm source. The rate in r/hr at a point near the source may be calculated and the chamber's response determined when it is placed at this point. Since the average energy of the gamma-rays from radium is approximately the same as the energy from cobalt-60, the correction factor obtained in this way should apply to cobalt-60. This method of calibration is the one used at the National Research Council and is discussed in the first paper.

The roentgen rate near a cobalt-60 source may also be deduced from measurements of the ionization current in absolute units produced in an ionization chamber of known volume and known wall material. Measurements were made in this way using the Saskatoon Cobalt Unit and the results are described in the second paper.

In the third paper a discussion is given relating the exposure in roentgens measured in air with a calibrated ionization chamber to the absorbed dose at the 100% point of the isodose curve in tissue.

Radiology Laboratory
National Research Council

Physics Department
University of Saskatchewan

THE JOURNAL OF THE
CANADIAN ASSOCIATION OF RADIOLOGISTS

Volume VI September 1955 Number 3

CALIBRATION OF COBALT UNITS USING RADIUM AS A STANDARD

C. GARRETT, M.Sc. and W. H. HENRY, Ph.D.
Division of Applied Physics, National Research Council, Ottawa

Calibration of the Ionization Chambers

In the method of standardization used at the National Research Council, a 25r Victoreen chamber was first calibrated on gamma radiation by exposing the chamber to the known output of a 250 mgm Ra source, encased in a capsule of 1 mm of silver. The output of this source had previously been precisely determined in two ways. In the first, the output was compared by means of air-wall ionization chamber measurements with that of a standard Ra source encased in 0.5 mm of platinum. From the latter's known content, and adopting the figure 8.4 r/hour at 1 cm for a 1 mgm source in 0.5 mm of platinum, the output of the standard, and hence of the capsule, were calculated. The second method was by direct calculation from the Ra content of the capsule, using an experimentally determined absorption coefficient for Ra gamma rays in silver. The two methods gave results agreeing to within 0.5%.

The calibration was carried out by exposing the chamber at not less than 20 cms from the radium source, the actual distance being measured during each exposure by means of a cathetometer. The source was suspended 1 meter above the floor by fine wires and the Victoreen chamber was held near its base by a light-weight stand, such that the full stem was irradiated, with no other objects within 80 cms. Exposure times of around 2 hours were used. The chamber was fitted with a lucite cap of 3 mm wall thickness in order to achieve electron equilibrium. The calibration factor, F_1, was then calculated from

$$F_1 = \frac{rt}{Rk}\left(\frac{100}{d}\right)^2$$

where

r = output of radium source at 1 meter

t = exposure time

d = distance (cms)

R = Victoreen scale reading

k = pressure temperature correction

The Victoreen chamber used had been altered in order to reduce leakage currents through either the insulator or extra-cavity air gaps. The insulator was replaced by one of amber, of low radiation-induced conductivity, and constructed in a manner eliminating the air space around the charging screw. Measurements made on this insulator showed that the leakage current was 0.1% of the current in the cavity, and had a variation with voltage and exposure rate such that a closely similar current would be produced by an increase in cavity volume of 0.1%. Since this same effective increase in volume applied to any exposure, including the calibration above, the calibration factor so obtained would be valid for any subsequent measurement.

Owing to the necessity of measuring outputs of very large sources of the order of kilocuries, it was considered advisable to use a 500r chamber in order to obtain accurately measurable exposure times. Such a chamber was made by replacing the usual Victoreen 25r thimble by a lucite thimble of 3mm wall thickness and appropriate volume. This chamber in turn was calibrated on gamma radiation by comparing its response with that of the 25r chamber. The two chambers were held in identical positions, one after the other, on a rigid arm which could be quickly swung into the gamma-ray beam, about 60 cms from a 300 curie cobalt-60 source contained in a lead castle. Then, calling F_1 and R_1 the calibration factor and scale reading of the 25r chamber in time t_1, and F_2 and R_2 the corresponding values for the 500r Victoreen chamber, in time t_2,

$$F_2 = \frac{F_1 R_1 t_2}{R_2 t_1}$$

The leakage currents in the 500r chamber, also of amber insulation, were measured to be 2.7% of the cavity ionization current. As in the case of the 25r chamber, their percentage contribution during chamber calibration was the same as during subsequent measurements, and so could be ignored as long as the entire chamber stem was irradiated each time. If a portion of the stem extended beyond the gamma-ray beam in any measurement, the

leakage was reduced by a proportionate amount and the calibration factor to be applied had to be increased by an equal proportion of the 2.7%.

The estimated errors in the calibration of the chambers as carried out above are 1% for the 25r chamber and 1.7% for the 500r chamber. Hence, it is felt that measurements of cobalt-60 outputs made using this method are accurate to ± 2%.

Calibration of Cobalt Units

The 500r chamber was used to measure the gamma-ray outputs of cobalt teletherapy units across Canada. As agreed upon at the National Cancer Institute meeting held in Winnipeg in October 1954, the measurements were made with the center of the chamber at a distance of 80.5 cms, in a field 10 cms x 10 cms. In the case of a rotating unit the measurement was made at the center of rotation, in the same field size.

It was found that the outputs as measured in this way were in many cases considerably higher than the output values previously in use at the clinics, the difference being as high as 10%. This was due, in part, to the previous measurements being made under the assumption that the Victoreen chamber calibration factor was the same on x-rays and on cobalt-60 gamma rays.

In Saskatoon, the measurement of the output of the teletherapy unit gave a value of 24.7 r/min on 1 January, 1955. This is in fair agreement with the measurement of 24.1 r/min as given in the following paper. There are indications that the accepted value of 8.4 for the radium output figure is high by about 2%. If these are confirmed, the above agreement will be considerably better.

Since all the cobalt units now in operation in Canada have been measured on the same basis, it should be possible to compare results obtained at different centers with considerably more confidence.

MEETINGS

THE CANADIAN ASSOCIATION OF RADIOLOGISTS

The 19th Annual Meeting will be held in Vancouver at the Hotel Vancouver, January 16th, 17th, 18th, 1956. Members are urged to send the titles of their papers now to: Dr. H. Brooke, 3195 Granville Street, Vancouver 9.

EIGHTH ANNUAL CONGRESS OF RADIOLOGY

In accordance with the decision of the International Committee of Radiology which met in Copenhagen in July 1953, the Eighth International Congress of Radiology will take place in Mexico City in 1956. The dates of the Congress will be July 22nd to 28th, 1956.

All national radiological societies have been asked to supply a list of their members, and full details about registration for the Congress will be sent to all radiologists individually as soon as they are available.

Correspondence should be addressed to the Congress Office at Calle del Oro 15, Mexico 7, D.F., Mexico.

EIGHTH ANNUAL CONFERENCE ON ELECTRICAL TECHNIQUES IN MEDICINE AND BIOLOGY

This Conference is sponsored by the American Institute of Electrical Engineers, Institute of Radio Engineers and Instrument Society of America, and it will be held at the Shoreham Hotel, Washington, D.C., November 14th, 15th and 16th, 1955.

REPORTS

INTERNATIONAL COMMISSION ON RADIOLOGICAL UNITS

A number of reports submitted to the International Commission on Radiological Units (I.C.R.U.), during its meeting at Copenhagen, July 1953, have been published as Supplement 117 of "Acta Radiologica" (Stockholm). This supplement may be obtained at the price of 25 Swedish crowns ($4.75 approx.) from "Acta Radiologica", Stockholm 2, Sweden.

REPORTS

INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION

The reports of the International Commission on Radiological Protection (I.C.R.P.) were recently published as Supplement No. 6 of the British Journal of Radiology. The price is 10/6d ($1.45 approx.) for paper cover or 12/6d ($1.72 approx.) for cloth cover editions, post free, and copies can be obtained from the British Institute of Radiology, 32 Welbeck Street, London, W.I.

CALIBRATION OF COBALT-60 USING ABSOLUTE IONIZATION MEASUREMENTS

H. E. JOHNS, D. V. CORMACK and G. F. WHITMORE
Physics Department, University of Saskatchewan and Saskatoon Cancer Clinic

Method of Measurement

In Saskatoon, the output of a 1000 curie Co^{60} beam therapy unit was determined by measuring the absolute ionization current produced in carbon and aluminum ionization chambers of known volume. The type of chamber used in making the ionization measurements is shown in Fig. 1. The outer wall

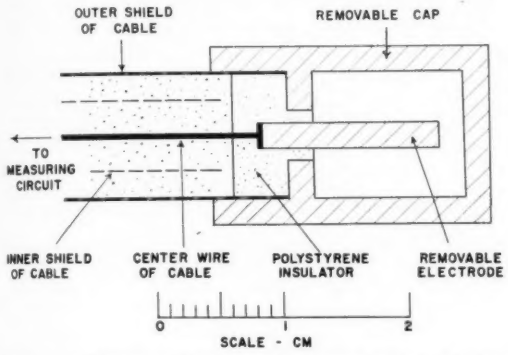

Fig. 1 — Diagram Showing the construction of the ionization chamber.

of the chamber is formed by a cylindrical cap of the chosen wall material and can be removed and replaced by a cap of some other material. This outer cap makes contact with the outer shield of a co-axial cable which supplies the collecting voltage. The central electrode of the chamber is a pin about 3 mm in diameter and is also removable. The central electrode is connected to the measuring circuit by means of the center wire of the co-axial cable. The inner shield of the co-axial cable is grounded. During irradiation the centre wire may be held at ground potential by con-

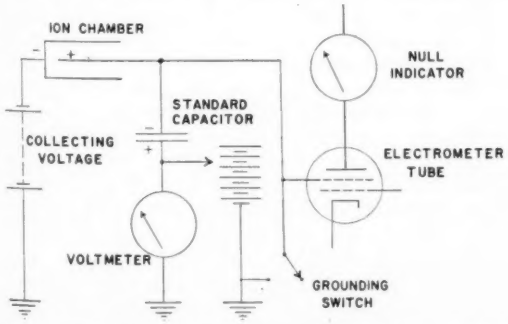

Fig. 2 — Schematic diagram of the measuring device.

tinually adjusting the voltage V (see Fig. 2). If this is not done, the central wire becomes more and more negative as the dose progresses reaching a value of about 10 volts for a large dose. The same ionization current was observed whether or not the central wire was held at ground potential indicating that leakage effects in the cable were negligible.

The ionization current was measured with the Townsend balance circuit shown in Fig. 2. The central electrode is connected by means of the co-axial cable to the grid of a miniature electrometer tube (Victoreen 5800). At the start of a run, the centre electrode and the grid are brought to ground potential by means of the grounding switch and a reading is made on a meter used as a null indicator in the plate circuit of the electrometer. The earthing switch is then opened and the irradiation is made. The ionization current through the chamber charges the grid and condenser to a negative voltage. After the run, the electrometer is restored to its original operating condition, as read on the null indicator, by raising the potential of the earthy side of the condenser to a positive voltage V. This compensating voltage was measured by means of a precisely calibrated voltmeter. If the capacity of the standard condenser is C, the total charge on it is CV which is equal to the total charge collected by the ionization chamber during the run.

The condensers used in the present measurements were standard air capacitors manufactured by the General Radio Corporation and the capacity values (500 and 1000 $\mu\mu$ F) were quoted to an accuracy of better than 0.1%. The meter used to measure the voltage V was calibrated with a precision potentiometer to an accuracy of $\pm$ 0.2%. The collecting voltage applied to the chamber was 60 volts which ensured saturation for the dosage rate of 25 r/min used in the experiment.

Several sizes of carbon chamber were used having volumes from about 1 cm^3 to 2.5 cm^3 and aluminum chambers with volumes about 1 cm^3 and 2.5 cm^3 were used. The volume of the chambers was measured by removing the end cap and filling the chamber with mercury. The end cap was then forced on to squeeze out the excess mercury. The mercury contained in the chamber was then weighed to give the chamber volume. These measurements were checked by calculation of the volume from measurements of the dimensions. The precise measurement of this chamber volume is the most difficult part of the experiment.

The chambers were exposed to the radiation from the Saskatoon Cobalt-60 Unit in the following way. The centres of the chambers were placed 80 cm from the source at the centre of a 10 x 10 cm field. The total charge collected during a known time was measured. The wall thickness for each of the chambers was slightly greater than that required to produce the maximum ionization current. The walls were 0.4 — 0.5 gm/cm^2 for the carbon chamber and 0.4 — 0.8 gm/cm^2 for the aluminum.

The results of the absolute ionization measurements are given in Table I. Measurements were made with four carbon chambers and two aluminum chambers. The ionization measurements were corrected using the values of temperature and pressure at the time of a run, to bring the values to esu per min per cm^3 of air at N.T.P. i.e. per 0.001293 gm of air to correspond to the definition of the roentgen.

Table I

Measurements of the dosage rate in r/min at a point 80 cm from the Saskatchewan 1000 curie Co^{60} unit, 10 cm x 10 cm field.

Date of Measurement	Chamber	esu* per 3 cm per min	Wall Attenuation Correction	Stopping Power Correction	Roentgens per min	
					Date of Measurement	Jan 1, 1955
Oct 12, 54	C-2.5 cm3	25.0	1.016	1.002	25.4	24.7
Oct 12, 54	A1-2.5 cm3	27.3	1.013	0.920	25.5	24.7
Oct 15, 54	C-1 cm3	24.5	1.016	1.002	24.9	24.2
Jan 26, 55	C-2.5 cm3	23.52	1.016	1.002	23.9	24.2
Jan 26, 55	A1-2.5 cm3	25.73	1.013	0.920	24.0	24.2
Jan 26, 55	C-1 cm3	23.72	1.022	1.002	24.4	24.5
April 8, 55	C-1.6 cm3	23.18	1.018	1.002	23.6	24.5
April 8, 55	C-1.2 cm3	22.99	1.018	1.002	23.5	24.3
April 8, 55	A1-1.2 cm3	25.00	1.031	0.920	23.7	24.5

*Corrected for air at N.T.P. Average 24.4 ± .2
Dosage rate at a point 80.0 cm from source 24.4 r/min.
Dosage rate at a point 80.5 cm from source 24.1 r/min.

The chambers were placed with their axes perpendicular to the direction of the radiation beam, with their centres in the centre of the beam and 80 cm from the source. The quantity of radiation reaching the centre of the chamber will be less than that which reaches this point in space when the chamber is not present. A correction was therefore made to allow for the radiation attenuation in the chamber wall. The effective attenuation coefficient was determined experimentally by increasing the front wall thickness of the chamber and was found to be 0.038 cm^2 per gm. The attenuation factors were calculated from the known thicknesses of the chamber walls and are shown in the fourth column of the table.

The quantity of radiation in roentgens is numerically equal to the number of esu per cm^3 of air in an "air-equivalent" chamber. For Co^{60} radiation the chief requirement of an "air-equivalent" chamber is that it should have the same stopping power per electron as free air. For materials such as carbon and aluminum which are not "air-equivalent" a correction must be made which is equal to the ratio of the stopping power per electron of the material to that of air. There is still no general agreement on the value of the stopping powers of air, carbon and aluminum; however the stopping power ratios given in the table appear to be the most reliable on the basis of present information.

The ionization values were multiplied by the correction factor for wall attenuation and stopping power to give the values of the dosage rate in roentgens per min at the time of irradiation. In order to compare results made at different times, all the values of r per min were corrected to Jan. 1, 1955 and these values are given in the last column of the table. These give an average value of 24.4 r per min as of Jan. 1, 1955 with a standard deviation of 0.2 r per min.

Reliability of Results

The possible error in the measured ionization current is estimated to be ± 0.3%, 0.1% due to uncertainty in the capacity value and 0.2% due to possible errors in the voltage calibration. The estimated possible errors in the volume measurements varied somewhat from one chamber to another, with a maximum value of ± 0.4%. The attenuation corrections are very small and the possible errors in them are correspondingly small, about ± 0.2%. Possible errors in the stopping power ratios are extremely difficult to assess. However, these will not affect absolute measurements of this kind to any greater extent than they affect the calibration with radium standards. If we neglect any possible errors from this last source the values of the dosage rate in r per min determined in this way should be accurate to ± 1%. This estimated error appears to be reasonable since the results in Table I taken with six different chambers at different times, with a variety of calibration procedures give a standard deviation of less than 1%.

Acknowledgments

The authors wish to thank the National Cancer Institute and the Saskatchewan Division of the Canadian Cancer Society for financial assistance in carrying out this project.

CALCULATION OF ABSORBED DOSE IN THE PATIENT FROM THE MEASURED EXPOSURE IN AIR

G. N. WHYTE, Ph.D.
Division of Applied Physics, National Research Council, Ottawa

The ionization chambers calibrated at the National Research Council are meant to measure gamma-ray exposure in roentgens. Following the recommendations of the Standardization Committee of the Radiological Society of North America, the term *exposure* is used here to refer to the property of the gamma radiation that is measured in roentgens, in order that the term *dose* may be confined to the concept of *absorbed dose*. To quote Technical Bulletin No. 1 of the Committee (1):

> The exposure is a property of the radiation only. The number of roentgens is a partial description of the x-rays at the place where it is measured or calculated. It tells nothing about what happens to the radiation or about the effects which it produces. It does not indicate whether the radiation is absorbed or passes through the region without absorption. It tells nothing about the material which it penetrates. It applies only to the radiation itself.

The *exposure rate*, which is measured in roentgens per minute, is related to the gamma-ray intensity; in fact, for a fixed energy spectrum, the exposure rate is proportional to the intensity.

The National Research Council calibration is aimed at making the chamber read roentgens at the point where the centre of the chamber is placed; that is, the chamber tells what the gamma-ray exposure would have been at that point in the absence of the chamber.

It may be worth mentioning that, since its walls are composed of material of low atomic number, a thimble chamber calibrated to read correctly for cobalt-60 gamma-rays should also measure roentgens at any other gamma-ray energy between about 0.2 and 1.2 Mev. (For energies below 0.2 Mev the photoelectric effect in the wall may affect the readings, and above 1.2 Mev the wall thickness may be inadequate to provide electron equilibrium.) Thus, if the gamma-ray beam contains radiation that has been scattered and degraded in energy, the chamber will still measure the total exposure.

The therapist, however, is not primarily interested in the exposure rate from the source; he is concerned with the *absorbed dose* in the patient, a quantity proportional to the energy absorbed per gram of tissue from the gamma-ray beam. The statement that one has delivered a dose of so many roentgens to a tumour presumably means that the tumour has absorbed an energy per gram equal to that lost by a roentgen of gamma radiation, i.e., one roentgen-equivalent-physical or rep.*

The distinction between absorbed dose and exposure becomes clearer when one considers the "build-up" portion of the depth-dose curve for cobalt-60 gamma-rays. For example, the exposure is greater at the skin than at a depth of 0.5 cm, since the incident intensity is attenuated somewhat in penetrating to this depth, but the absorbed dose at the skin is *less* than at a depth of 0.5 cm, because the secondary electrons through which the energy is actually transferred to the tissue have not built up to an equilibrium with the gamma-rays. (See Fig. 1).

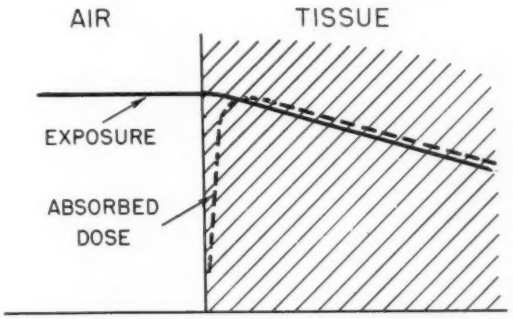

Fig. 1 — Variation of exposure and absorbed dose as a function of depth in tissue.

The problem then is, knowing the gamma-ray exposure rate at a point in free air in the absence of the patient, to find the absorbed dose rate at a point in the patient. Or, since depth-dose and isodose curves for soft tissue are available for a variety of irradiation conditions, this may be reduced to finding the absorbed dose rate at the maximum of the depth-dose curve; and further, since at any point beyond the maximum in soft tissue the absorbed dose in rep is numerically equal to

---

**As used here, the rep is defined as the energy per gram absorbed by soft tissue from a roentgen of gamma radiation. It is equal to 93 ergs/gm. The International Commission on Radiological Units has recommended the use of the* rad, *equal to 100 ergs/gm, as the unit of absorbed dose. Thus one rad is equal to about 1.08 rep.*

the exposure in r, it will suffice to determine the exposure rate at the maximum of the depth-dose curve.

The first step is to measure the exposure rate in free air at the point where the maximum of the depth-dose curve will occur, i.e., in the case of cobalt-60, at the source-to-skin distance (SSD) plus 0.5 cm. When the patient is put in position, this rate will be changed by two factors: backscattering from the patient, which will increase the radiation, and attenuation in the 0.5 cm of tissue, which will decrease the radiation. The combined effect of these two factors can probably best be determined by measuring the ratio of the ionization currents in a small cavity chamber placed first at the SSD + 0.5 cm in the phantom and then at the same point in free air. The chamber should have a small air volume (not more than 1 or 2 mm deep) and an equilibrium wall of about the same density as the phantom, so that the fact that the chamber displaces an equal volume of phantom material will not change the exposure rate at its centre.

The method of deriving the exposure rate in the phantom from the ratio of the cavity-chamber readings can be seen with the aid of Fig. 2. Assume that when the exposure rate at the centre of the cavity chamber is I the reading of the chamber is $R = kI$. Then the reading in the phantom will be $R_1 = kI_1$ and the reading in air will be $R_2 = kI'_2 = kI_2\, e^{-ux}$,

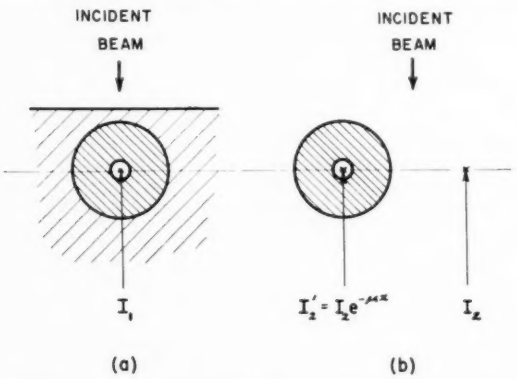

Fig. 2 — Arrangement for determining the conversion factor, f.
(a) Cavity chamber in phantom.
(b) Cavity chamber in free air.

where I_1 is the exposure rate at a depth of 0.5 cm in the phantom, I_2 is the exposure rate in free air, I'_2 is the exposure rate at the centre of the chamber in free air, u is the attenuation coefficient of the radiation in the chamber wall material, and x is the wall thickness. (In low-atomic-number material u is about 0.035 cm^2/gm and x for an equilibrium wall is 0.4 gm/cm^2, so that e^{-ux} is about 0.986.) Then

$$f = \frac{I_1}{I_2} = \frac{R_1}{R_2}\, e^{-ux},$$

where f is the factor by which the exposure rate measured in free air must be multiplied in order to get the exposure rate at the maximum of the depth-dose curve in tissue. As mentioned above, the absorbed dose rate at the maximum in rep/min is then, to a close approximation, numerically equal to the exposure rate in r/min.

Values of the conversion factor, f, for cobalt-60 radiation, based on recent measurements made in the manner outlined above in this laboratory and by H. F. Batho of the British Columbia Cancer Institute*, are presented in Table I for a number of field sizes.

Private communication.

Table I
CONVERSION FACTORS FOR COBALT-60

Field size (cm.)	f
5 x 5	1.01
7 x 7	1.02
10 x 10	1.03
15 x 15	1.05
20 x 20	1.06

The factors listed apply to a source-to-skin distance of 80 cm., but they should not be in error by more than 1% for distances between 60 and 120 cm. An example will illustrate the use of the table:

Example

Source-to-skin distance = 80 cm. Field size = 10 x 10 cm. Exposure rate in free air measured at 80.5 cm. = 30.0 r/min. Conversion factor for 10 x 10 cm. field (from Table I) = 1.03. Exposure rate at maximum of depth-dose curve = 30.0 × 1.03 = 30.9 r/min.
∴ Absorbed dose rate at maximum of depth-dose curve = 30.9 rep/min. or 30.9 x 0.93 = 28.9 rad/min.

Finally, the published depth-dose and isodose curves (2,3,4) enable one to estimate the absorbed dose at other points in the patient.

REFERENCES

1. Quimby, Edith H. and Laurence, G. C., The Radiological Society of North America Standardization Committee, Technical Bulletin No. 1. Radiology, 1940, 35, 138-159.

2. Dixon, W. R., Garrett, C., and Morrison, A., Cobalt-60 Teletherapy Unit: Output, Depth Dose and Isodose Distributions. National Research Council Report No. 2667.

3. Johns, H. E., The Physics of Radiation Therapy. Charles C. Thomas, Springfield (1953).

4. Braestrup, C. B., and Mooney, R. J., Physical Aspects of Rotating Telecobalt Equipment. Radiology, 1955, 64, 17-27.

CANCER OF THE LIP

T. A. WATSON, M.B., Ch.B. and C. C. BURKELL, M.D.
Saskatoon, Saskatchewan

Cancer of the lip presents an interesting therapeutic problem. Its natural history from its inception as an accessible growth or ulcer arising from the vermilion surface of the lip, to the final stage of sepsis, necrosis and metastatic spread is well known. Yet it is a disease which, if adequately treated, yields quite gratifying results. This paper deals with the radiological management of 1884 pathologically proven cases of cancer of the lip treated in the Saskatchewan Cancer Clinics from 1932 to 1953.

It is a disease which affects all age groups, but as one would expect, the incidence of the disease is greater among the elderly. This is shown graphically in Figure 1. Oddly

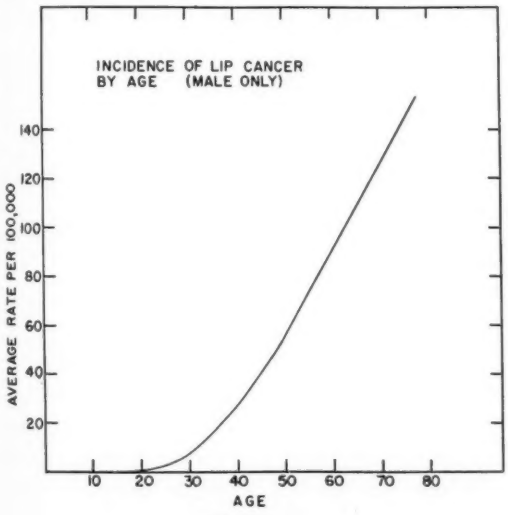

Figure 1

enough, however, when it occurs in the younger patient, it is more apt to belong to a lower histological grade. As shown in Figure 2, the percentage of patients having a histological Grade 1 lesion is much greater among the younger patients. The Grade 2 and Grade 3 lesions become progressively more common with advancing years. That is, the disease occurs in a less malignant form in younger patients, and their chance of surviving five years or more is greater. This is indirectly shown in Table I where the crude survival rate by grade is illustrated. Analysis of our figures shows that cancer of the lip is much commoner in agricultural and outdoor workers than in those not exposed so much to the elements.

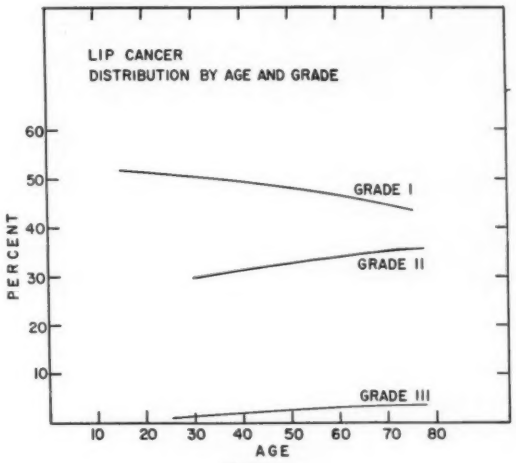

Figure 2

TABLE I
Cancer of the Lip
Crude Survival by Grade
1932-48

	% survived 5 or more years
Grade I	84.8
Grade II	79.9
Grade III	56.1
Not stated	80.2

Cancer of the lip is almost always an epidermoid cancer, although from 1932-48, five cases of basal cell carcinomata and four of baso-squamous carcinoma were encountered. It occurs in most cases on the lower lip (97%) and usually as frequently on one side as the other. Carcinomata of the upper lip tend to be more anaplastic. The site of the lesion, in this series, is shown in Table II. There is a marked sex difference in incidence — 98% are males.

TABLE II
Site of Cancer on the Lip
1932-53

	R side	L side	Mid	All of lip	Total
Lower lip	731	768	303	20	1822
Upper lip	22	23	7	2	54
Not stated					8
Total					1884

Some patients have a history of a pre-existing lip disease; 10.7% had a definite history of chronic ulcer, leukoplakia, inflammatory epithelial hyperplasia, or other disease before the development of the cancer, (Table III). Syphilis, as a pre-existing disease, was

TABLE III

Pre-Existing Disease
1932-53

Pre-existing Disease	No. of cases	%
None	1588	84.3
Chronic ulcer	54	2.9
Leukoplakia	74	3.9
Inflammatory epithelial Hyperplasia	40	2.1
Other	34	1.8
Not stated	94	5.0
Total	1884	100

extremely uncommon in this series. Other cancer of the lip, either previously or simultaneously, was fairly common, however. In fact, 7.5% of these patients had such a lesion whereas only 5% had cancer elsewhere indicating, we believe, a much greater susceptibility of the lip in these patients to the development of a cancer (Table IV).

TABLE IV

Cancer of the Lip
Other Cancer in same Patient
1932-53

		Number	Per cent	
Total cases		1884	100	
Ca. of other part of lips	Simultaneous	60	3.2	7.5
	Previous	81	4.3	
Other Cancer	elsewhere	94	5.0	

Our method of staging cancer of the lip is as follows:

Stage I — Growth less than 3 cms. in greatest diameter. Not fixed to deeper structures. Does not interfere with mobility of organ.

Stage II — Primary as in Stage I. Mobile secondary nodes confined to the immediate drainage area.

Stage III — Growth larger than 3 cms. in greatest diameter or involment of deeper structures or impairment of mobility of the organ. Mobile secondary nodes may be present, confined to the immediate drainage areas.

Stage IV — Fixed secondary nodes or nodes in more than one drainage area or distant metastases.

Most of our cases (85.3%) occurred in Stage I (Table V). That this method of staging is of a direct clinical significance is shown in Tables VI and VII. In Table VI the crude five-year survival rate is compared to the size of the lesion when originally seen. This shows a progressive decline in survival with an increase in size. Table VII includes factors other than size and it, too, shows a progressive decline in survival with advanced stage of the disease.

TABLE V

Staging of Cancer of the Lip
1932-53

STAGE	No.	%
Stage I	1608	85.3
Stage II	39	2.1
Stage III	81	4.3
Stage IV	10	0.5
Previously treated or unstated	106	7.8
Total	1884	100

TABLE VI

Cancer of the Lip
Survival Related to Size of Lesion
1932-48

	Less than 1 cm.	1 -1.9 cms.	2 - 2.9 cms.	3 cms. and over	Unstated	Total
Total cases	605	364	82	54	216	1321
% crude 5 year survival	86.4	81.3	73.2	48.1	78.7	81.4

TABLE VII

Cancer of the Lip
Survival related to clinical staging
1932-48

	Stage I	Stage II	Stage III	Stage IV	Previously treated or unstaged	Total
Total cases	1097	34	69	9	112	1321
%crude 5 year survival	84.1	64.7	52.2	0	84	81.4

Metastases

Only 4.3% of the patients had lymph node metastases when first seen, (Table VIII). These patients had delayed seeking medical attention on an average of 21.6 months as compared to 13.7 months' delay for the whole series. Most of them, as would be expected, had either a histological Grade 2 or Grade 3

TABLE VIII

Cancer of the Lip
Secondary Nodes when first seen 1321 cases
1932-48

How proven	No. of patients	Average delay in months	How treated		5 year survival
Clinical Nodes	46	22	Radiation No treatment	39 7	15 0
Path. Nodes	11	20.5	Radiation Surgery	4 7	0 3
Total	57	21.6		57	18

lesion. The criteria for diagnosing these lymph node metastases was not as rigid as one would wish but those diagnosed on clinical grounds were said to have hard, enlarging or fixed, non-tender lymph nodes in the immediate lymph drainage areas and not connected with any other demonstrable cause. The treatment method and five year survival of these patients are shown in Table VIII.

An additional 56 patients or 4.2% developed nodes after successful treatment of the primary. The time of appearance of these nodes varied considerably — in fact, from one month to eight years. The average time of appearance was, however, 22.9 months. The method of treatment and the five-year survival of these patients is given in Table IX. We consider that, when feasible, the method of choice of secondary nodes in the neck is radical surgery, in the form of block dissection. Prophylactic block dissection is not reasonable since the incidence of nodes in this disease is very low.

TABLE IX

Cancer of the Lip

Nodes which Developed Subsequently to Treatment of Primary 1932-48

How proven	No. of patients	Average time of appearance	How treated		5 yr. survival after treatment of nodes
Clinically	24	22 mos.	Radiation	21	5
			No treatment	3	0
Pathologically	32	23.5 mos.	Radiation	9	0
			No treatment	1	0
			Surgery	22	9
Totals	56	22.9 mos.		56	14

Treatment and Results

From 1932 to 1948 a total of 1665 patients suffering from cancer of the lip have been admitted to one of the two Cancer Clinics in Saskatchewan. Of this number, for one reason or another, 344 cases were not proven pathologically. Accordingly, there are left 1321 pathologically proven cases for five-year analysis. Of this number of patients 1075 are known to have survived five years — a crude survival rate of 81.4%. When this rate is corrected for probable death from other causes (according to the number in various age groups — correction factor = .873) the corrected five-year survival rate is 93.2%. This figure may be compared with a gross survival rate (well five years following original treatment) of 95.7%, in which the indeterminate cases have been excluded. (See Table X.)

TABLE X

Five Year End Results in Cancer of the Lip

Saskatchewan Cancer Clinics 1932-48

Total number of patients treated (1932-48)	1321
Indeterminate group	
Died of other causes and without recurrence	158
Lost track of without recurrence	27
Dead — cause uncertain	13
Total number of indeterminate group	198
Determinate Group (total number minus indeterminate group	1123
Failures:	
Dead as a result of cancer	29
Well but have had a recurrence within five years	64
Total number of failures of original treatment	112
Successful results	
Free from disease after five years or more	1011
Five year end results: Successful results / Determinate group	$\frac{1011}{1123} = 90\%$
Gross survival — well five years following original treatment	$\frac{1075}{1123} = 95.7\%$

Treatment Method

We consider that radiation is the treatment of choice in cancer of the lip. Surgery can be successful in a large number of patients but it is contended that the complexity of treatment, the necessity for hospitalization of the patient and the possibility of resulting scars and defects of the lip are disadvantages. Radiation methods of various types, as long as they are radical in nature, are successful, and the cosmetic results are usually good. The methods of treatment used in these cases has been quite diverse and therefore lend themselves to a considerable degree of comparison, with respect to cure rate, complications, and cosmetic effect. The methods of treatment which have been used are as follows:

(a) A large number of these cases have been treated by radium implantation. In one of the Saskatchewan Cancer Clinics this has been the standard method of treatment of most cases for a very long period. The actual method used has been an empirical one using needles containing .6 mgms. radium. These needles are of a total length of 1.6 cm. with an active length of 1.0 cm. The needles are inserted antero-posteriorly through the lip in a single line with a ½ cm. spacing, the number of needles depending on the extent of the lesion. Usually a 1 cm. margin is left at each side. The needles are left in place for seven days. The average dose given by this empirical method varies from 4500 roentgens to 7700 roentgens ½ cm. from the line of the implant. The dose in the centre of the implant is by no means constant — the larger the number of

needles, the higher the dose in the centre. This dose may rise to very considerable proportions when a large number of needles are used and under these circumstances, a central defect is not an uncommon final occurrence. This treatment, of course, must be limited to smaller lesions on the vermilion border of the lip and cannot be used when there is extension towards the chin.

(b) Radon seed implantation — For moderate sized lesions a permanent radon gold seed implant, under local anaesthetic, may be made in the form of a semi-circle with or without central seeds, depending on the size of the implant. The distribution of the seeds is according to the Patterson-Parker rules and the dosage aimed at is 6500 roentgens ½ cm. from the plane of the implant. The diameter of the semi-circle follows the vermilion border of the lip. X-ray films are taken of each placement, and the actual dose delivered calculated.

(c) Multiple X-ray treatments — Most of these treatments consisted in three exposures of 200 Kv. X-rays on alternate days, each of 1000 r. The rest of the mouth is protected by lead shielding behind the lip. The lead used is preferably covered with a thin layer of wax to prevent excessive back-scatter on to the mucosa of the lip. By this method virtually a homogeneous dose is administered throughout the lip, the treating distance being usually 40 cm.

(d) Single X-ray treatment — This method was tried in a limited number of cases (52) using a similar arrangement to that for multiple X-ray treatment, the surface dose being 2000 roentgens. This treatment has now been abandoned for reasons which will appear presently.

(e) Miscellaneous Methods — For some extensive lesions double radium or radon moulds have been used and other combinations of radium, radon or X-ray. In a few very small lesions an excisional biopsy has been shown pathologically to be complete and no further treatment has been given. Surgery, however, has not been used as a routine treatment.

It will be seen from Table XI that radium implantation has been the commonest form of treatment, followed by multiple X-ray treatment. It should be emphasized that some selection of cases took place in that a certain number of the larger lesions tended to be treated by multiple X-rays rather than radium implantation. Thus, no exact comparison as to results is possible between these methods of treatment. This point is brought out by Table XII in which it is noted that a somewhat larger percentage of Stage II and Stage III cases were treated by multiple X-ray than

TABLE XI

Cancer of the Lip

Treatment Method

Type of treatment	No. of patients treated	%
Radium implant	735	55.6
Radon implant	90	6.8
X-ray single	52	4.0
X-ray multiple	253	19.1
Miscellaneous	75	5.7
Not treated	116	8.8
Totals	1321	100.0

N.B. Not treated because

a) too advanced	2
b) went elsewhere	1
c) Prev. treatment adequate	41
d) Treatment of recurrence	72
	116

TABLE XII

Cancer of the Lip

Treatment Method Related to Clinical Stage (ie) Selection of Cases for treatment) 1932-48

	Number of patients treated in each stage				
Type of treatment	Stage I	Stage II	Stage III	Stage IV	Totals
Radium implant	679	13	38	4	734
Radon implant	79	6	4	0	89
X-ray Single	51	0	1	0	52
X-ray Multiple	221	10	18	3	252
Miscellaneous	61	5	8	1	75
					1202
			Not treated		116
			Unstaged		3
			Grand total		1321

TABLE XIII

Cancer of the Lip

Results by Treatment Method 1932-48

Type of treatment	No. of patients	Crude 5 year survival
Radium implant	735	81.6
Radon gold seed	90	84.4
X-ray single	52	80.8
X-ray multiple	253	78.3
Other forms of treatment or prev. treatment adequate or treatment of recurrence	191	83.2
Total	1321	81.4

by radium implantation. It should be noted from this table that the type of case on which radium and radon implantations have been done are roughly comparable as regards to stage and those to which single X-ray treatment were given were almost all Stage I. The miscellaneous cases are too small for any statistical analysis. Table XIII demonstrates the

crude five-year survival rate on patients treated by these various methods. The highest survival rate is amongst those who had a radon gold seed implant, but the figures are perhaps not high enough in this category to be statistically significant. It should be noted that in all these radiation methods the crude five-year survival rate is very similar. No conclusions can be drawn from the column at the bottom since some of these patients were highly selected (some had been well for a considerable time before coming to the clinic for follow-up purposes only). Table XIV shows a high percentage of treatment failures in the single X-ray treatment method. The treatment failures for multiple X-ray are also rather high but it should be remembered that these cases tended to be in later stages than the radium and radon gold seed implantation. The lowest number of recurrences in the treated area are for radon gold seed implant but the number of the cases involved is quite small.

TABLE XIV

Cancer of the Lip

Primary Treatment Failures

1932-48

Type of treatment	No. of patients treated	Non-Resolution	No. of recurrences	%
Radium implant	735	9	24	3.3
Radon gold seed implant	90	0	2	2.2
X-ray single	52	0	8	15.4
X-ray multiple	253	9	21	8.3
Miscellaneous methods	75	1	9	12.0
Totals	1205	19	64	6.3%

N.B. — 116 patients excluded because

a) too advanced	2
b) went elsewhere	1
c) Prev. treatment adequate	41
d) Treatment of recurrence	72
	116
Primary treatment	1205
Grand total	1321

In all these methods of treatment the reaction is similar — there is a fairly intense mucosal reaction and a moist reaction over the skin which heals four to six weeks following the treatment. Table XV shows the complications of primary treatment. These are least for radon gold seed implant and most for single X-ray treatment method. They are quite low in radium implantation.

One of the important considerations in the choice of method in such an obvious part of the body as the lip is the cosmetic result. In cases treated by radium implantation there is frequently a depressed atrophic central scar, sometimes with telangiectasia. Multiple X-ray

TABLE XV

Cancer of the Lip

Primary Treatment Complications

1932-53

Treatment Method

	Radium implant	Radon gold seed implant	X-ray single	X-ray Multiple
No. of patients	1007	164	70	383
Necrosis of lip and/or jaw	3	0	9	22
Deformity	10	1	0	5
Non-resolution	12	0	0	13
Totals	25	1	9	40
Percentage Complication	2.5%	0.6%	12.9%	10.5%

treatments also show an atrophy of the skin in the treated area and this atrophy stops suddenly at the edge of the treatment field. This sudden change between atrophic and normal skin tends to accentuate the presence of abnormality on the patient's face. The same is true, to a larger degree, in the patients treated with single X-ray treatment. The best cosmetic results by far in this series are the cases treated by radon seed implantation. It is felt that from the point of view of cosmetic result, radium or radon is superior to X-ray since there is no sharp edge to the treated area and any changes in the treated area, therefore, will merge slowly with the surrounding normal skin.

Comparison of Radiation Methods

It is felt that these methods can be judged by the following criteria:

1. The success of the method in curing the disease.
2. The frequency of complications.
3. The inconvenience to the patient in having the treatment performed.
4. The simplicity of the method.
5. The cosmetic result obtained.

There is very little difference in the apparent cure rate produced by the various radiation methods mentioned. The radium and radon implantation is perhaps a little superior to the X-ray methods. From the point of view of complications (necrosis and non-resolution) however, radium implantation and particularly radon seed implantation seem considerably superior. The inconvenience to the patient is minimal with a single X-ray treatment but this method has been abandoned for other reasons which have been mentioned. Radium implantation implies the admission

of the patient to hospital for seven or eight days. Multiple X-ray treatment means that the patient does not need to come into hospital but he must attend as an out-patient for a varying length of time. In the case of permanent radon seed implantation, the procedure can be done easily as an out-patient in five or ten minutes and he can then go home, the only proviso being that radon seeds should be readily available. From the point of view of simplicity both the radon seed implantation and single X-ray treatment are ideal. Finally we are of the opinion that the cosmetic result is best, in our hands, with the permanent radon seed implantation.

Conclusions

Radiation treatment of cancer of the lip can be very successful both from the point of view of cure, cosmetic result, and lack of inconvenience to the patient. Permanent single plan radon gold seed implantation is an excellent method in the treatment of the majority of cases of cancer of the lip.

Acknowledgment

Much of the statistical data presented was produced with the assistance of Dr. M. Acker, Director of Research and Statistics, Department of Public Health, Province of Saskatchewan.

Announcement of

AWARDS IN RADIOLOGICAL RESEARCH

of the James Picker Foundation

On behalf of the James Picker Foundation, the National Academy of Sciences-National Research Council announces the continued availability of funds in support of radiological research. Applications are reviewed by the Committee on Radiology of the Academy-Research Council's Division of Medical Sciences. Final determination of awards is made by the Foundation upon recommendation of the Committee. The interests of the Foundation are oriented toward, but not necessarily limited to, the diagnostic aspects of radiology. Awards are not restricted to citizens of the United States. Applications for the fiscal year 1956-1957 must be submitted on or before December 1, 1955.

Grants-in-aid are designed to encourage research offering promise of improvement in radiological methods of diagnosis or treatment of disease.

Grants for Scholars are a transitional form of support, designed to bridge the gap between the completion of fellowship training and the period when the young scientist has thoroughly demonstrated his competence as an independent investigator. A grant of $6,000 per year will be made directly to the Scholar's institution as a contribution toward his support, or his research, or both. Initial grants are limited to one year, but renewal may be recommended. Applications should be submitted by the institution on behalf of the candidate.

Fellowships in Radiological Research, available under the program of the Foundation, are being announced separately.

Further details and application blanks may be obtained from the Division of Medical Sciences, National Academy of Sciences-National Research Council, 2101 Constitution Ave., N.W., Washington 25, D.C.

FOETAL ACHONDROPLASIA

H. P. KENT, M.A., M.B., B. Chiv., D.M.R.D.
Regina, Saskatchewan

Continuous improvements in radiographic technique, both for the demonstration of the position of the placenta in the uterus, as well as for the condition of the foetus have led to the recognition of an increased number of foetal abnormalities. Only a few cases of foetal achondroplasia have been described, and it is the purpose of this paper to place a further case, recognized in utero, on record.

Case record

Mrs. E. R., born 1921, attended for antenatal care during late 1952 until April 1953. She had 2 previous confinements, in 1946 and 1947, and although instruments were used during delivery on each occasion, there had been no complications and both children were normal and doing well. In 1944 the patient had an appendicectomy, but apart from this she and her husband were both well. There was no family history of dwarfism, but the husband's mother had been delivered of a stillborn child with a large head.

The menstrual history was normal, the last cycle having occurred in July of 1952. Pregnancy proceeded normally, quickening being noted in December 1952. Throughout the pregnancy there was no headache or vomiting, and no swelling of the ankles occurred. The blood pressure remained normal, and urine findings were consistently negative. The haemoglobin was 80% at the first attendance, and the Wassermann reaction negative. The blood group was 0, Rh positive. The foetal position was unstable. On April 24, 1953, the foetus had turned to a frank breech, and the patient was admited to the Regina General Hospital.

On April 26, 1953, the foetus was rotated to the vertex position under general anaesthesia. Delivery took place on April 30, 1953, taking 1 hour and 38 minutes, and proved difficult. Following episiotomy a midforceps delivery had to be performed. The placenta and membranes were found to be intact. Blood loss was profuse. The condition of the live female foetus, weighing 6.5 lbs. was fair at birth, but the baby died on May 2, 1953. The child had the typical appearance of an achondroplastic dwarf.

Radiology

A pelvimetry had been performed on April 24, 1953. In the antero-posterior view the foetus was seen to present by the breech, with the head high in the fundus. The head extended well back on the spine. Later films, obtained on April 25 and April 27, 1953, showed (Fig. 1) that the foetus had been turned into a vertex position and that the head presented by the brow, with the occiput posteriorly and to the right as shown in a lateral view. The head was again hyperextended on the spine, and considered to be large. The foetal abnormality was noted and additional views were requested.

Fig. 1. A.P. view of abdomen. Brow presentation of the hyperextended head.

Several views to demonstrate foetal detail were taken, and in one of the oblique views an excellent profile of the foetus (Fig. 2) was obtained, demonstrating the classical features of achondroplasia.

The large foetal head remained extended on the cervical spine, which was lordotic. No evidence of fusion between occiput and upper cervical spine could be detected. No foetal thyroid tumour was visible, as indicated by the fat line in the neck of the foetus. The dorsal spine was lordotic, whereas in the dorso-lumbar spine the curve was kyphotic. All vertebral bodies were flattened, and the disc spaces wide, having approximately twice the width of the vertebral bodies in the dorso-lumbar region. The abdomen appeared large,

Fig. 2. Oblique view. Profile of achondroplastic foetus.

again as indicated by foetal fat. The thorax was only about half the size of the abdomen, the ribs appearing short. The foetal abdominal wall seemed intact. All the limbs were short, the long bones broadened, as were the metacarpals and metatarsals. The density of the foetal skeleton appeared normal. A detailed search revealed no obvious fractures. With the exception of the head the general appearances of the foetus in this profile view markedly resembled a Dachshund.

Figures 3 and 4 were obtained after death. The relative size of the head to the remainder of the skeleton is shown. Additional features, typical of the condition, and not as well seen on the "in utero" films are the widening of the

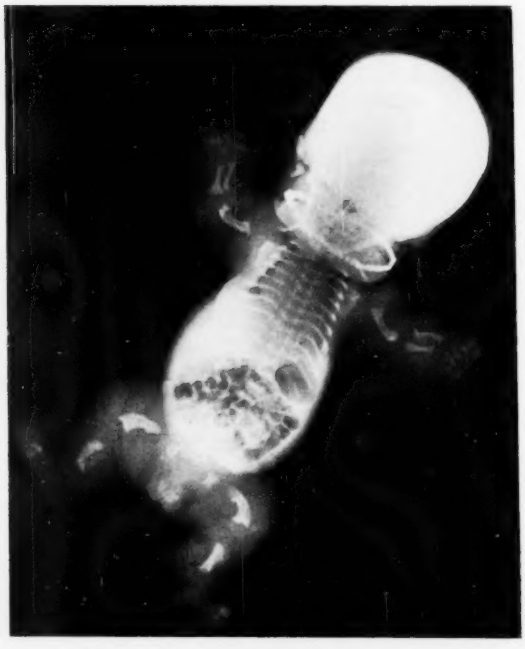

Fig. 3. Post-mortem AP view of foetus.

Fig. 4. Post-mortem lateral view of foetus, showing classical achondroplastic features.

ends of the diaphyses of the long bones, the broadening of the anterior ends of the ribs and the rolls of fat encircling the extremities.

Necropsy findings

The pathological examination was carried out by Dr. W. H. Houston. On external examination the appearance was that of achondroplasia. The crown-rump measurement was 34 cms. The trunk appeared of normal length The head was much larger than normal, with prominence of both frontal and occipital regions.

In the thorax thyroid and thymus were normal. The lungs (right 12g., left 10g.) were lying free in the pleural space, which was wide at the bottom and narrow at the top. The lungs were much smaller than normal and showed only rudimentary interlobar fissures, but the bronchi were normal. The lung parenchyma was deep red in colour and very poorly aerated. The lungs floated sluggishly in water. The pulmonary vessels were normal.

The heart (12 g.) was of normal size and shape. The ductus arteriosus and foramen ovale were both patent. No congenital defects were found in the heart. The peritoneal cavity and the gastro-intestinal tract showed no abnormality. Liver, spleen, kidneys and lower urinary tract were normal.

The head was much larger than normal, the sutures were widened and the fontanelles dilated. The scalp was oedematous. A bony abnormality was present in the region of the foramen magnum, where three protuberances were found, two anteriorly, and one posteriorly, encroaching on the foramen and apparently compressing the cord. A small subdural haemorrhage was present in the parietal region. The medulla appeared to be shortened anteroposteriorly, but otherwise the brain showed no abnormality.

Histological examination of the lungs revealed scattered areas of collapse. Around some of the collapsed areas there was a moderate emphysematous change. (Fig. 5.) The alveolar walls were, on the whole, thicker than normal and the lung tissue was markedly congested. The bronchi appeared reasonably well developed and showed no pathological features. The pleural surface of the lung was oedematous.

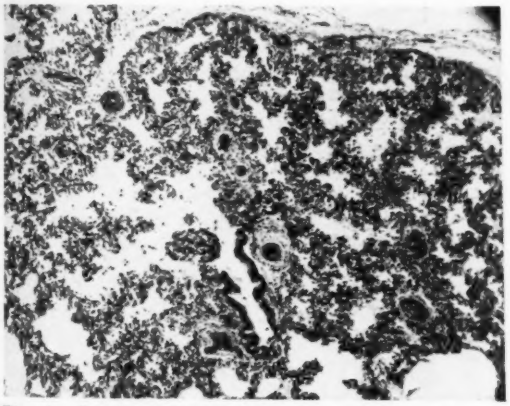

Fig. 5. Section of hypoplastic lung showing patchy collapse of the lung and thickening of the alveolar walls.

The pathological diagnosis was: 1) achondroplasia, 2) pulmonary hypoplasia.

Comment

Achondroplasia is a genetic disturbance of growth involving bones laid down in cartilage, and is transmitted as a mendelian dominant character. Several synonyms are in use for this condition, among which Cocchi[3] mentions chondrodystrophy and osteo-chondrodystrophy foetalis. In fact, he prefers the term chondrodystrophy, and although this is certainly a more correct term as regards pathology, to avoid confusion the term achondroplasia is used. This has the merit of immediately calling to mind the classical short limbed dwarf known for centuries over the whole world. Caffey[2] and Potter[9] refer to three types of the disease, as originally distinguished by Kaufmann in 1892: a) the hyperplastic type, b) the hypoplastic type and c) the malacic type, but Shelling[11] states that these are only variations of the same disease process.

Fairbank[4] has stated that achondroplasia is the commonest type of dwarfism. Nevertheless only 8 cases were seen by Potter[9] in 60000 deliveries at the Chicago-Lying-in Hospital. Seven of these children died soon after birth, which is in accordance with the well known fact that few achondroplastic dwarfs survive the first year of life, and that many die before birth. The surviving infant in Potter's[10] series had achondroplastic parents, and was known to be alive and well at 9 months.

Hartley[5] draws attention to the fact that achondroplasia is a rarity amongst foetal skeletal defects demonstrable in utero, but was able to make the antenatal diagnosis in 6 cases over a period of 12 years[6]. In two of his series of cases the foetus presented by the brow, similar to the case under discussion once version had been performed. Judging on these few available cases it is apparent that foetal malpresentation is common in achondroplasia. One of Hartley's cases was an achondroplastic foetus with additional cranial deformities, consisting of oxycephaly, craniostenosis, hydrocephalus and craniolacunia. The only other case known to the writer is that described by Haynes & Wangner[7], where a cyclops monster of achondroplastic type was delivered by a patient who at the next delivery had a child suffering from chondroangiopathia calcarea seu punctata, also with achondroplastic limbs.

The radiological differential diagnosis of achondroplasia seen in utero includes osteogenesis imperfecta, as noted by Aitken and colleagues[1]. This was indeed briefly considered as a possibility in the present case, particularly in view of the short limbs. The absence of visible fractures and the normal density of the skeleton excluded this diagnosis. Hartley[5] states that the relative flat outlines of the vertebral bodies together with the relatively short and thick limbs are sufficient to establish the diagnosis of achondroplasia.

It is not intended to enlarge on the radiological features of achondroplasia apart from those given in this case report. But it does appear worth stressing two pathological features in connection with the death of this child 2 days after birth. Potter[9] in her discussion on the pathology of the condition mentions that death may occur from secondary plumonary hypoplasia, the result of the chest wall deformity. This is corroborated in the present case, where pulmonary hypoplasia was noted at necropsy. The other interesting feature is the deformity of the foramen magnum, taking the form of bony encroachment from both sides anteriorly, and posteriorly,

thus reducing the size of the foramen and compressing the cord. This feature is mentioned by Potter[9], Neale[8], and Shelling[11], and considered a cause of premature death. The explanation of the deformity of the foramen magnum is premature synostosis of the segments of the occipital bone, similar to the well known change in the os tri-basilare. It is speculative which of these causes led to the premature death of the infant under discussion.

Summary

(1) A case of foetal achondroplasia, recognized in utero, is described.

(2) Although achondroplasia is a common form of dwarfism, only 2 cases recognized in utero have been reported in the literature.

(3) The incidence of foetal malpresentation would appear to be increased in achondroplasia.

(4) The radiological differential diagnosis is briefly described.

(5) Pulmonary hypoplasia and bony encroachment on the foramen magnum, compressing the cord, were the outstanding pathological features in the described case, leading to premature death of the infant.

Acknowledgment

The author wishes to thank Dr. J. A. Brown for the use of the case records, and Dr. W. H. Houston for the pathological reports.

BIBLIOGRAPHY

1. Aitken, G. W. E., Cohen, A. & Verco, P. W., Osteogenesis imperfecta, J. Faculty of Radiologists, 1954, 6, 62.

2. Caffey, J., Pediatric X-ray Diagnosis, Year Book Publishers, 1950, 632.

3. Cocchi, U., Chondrodystrophy in Schinz, Vol. 1., 1950, 653-662.

4. Fairbank, Sir T., An Atlas of General Affections of the Skeleton, Livingston Ltd., 1951, 142-145.

5. Hartley, J. B., Foetal Abnormalities, Modern Trends in Diagnostic Radiology, 1948 1st Series, 381.

6. Hartley, J. B., Personal communication, 1955.

7. Haynes, E. R. & Wangner, W. F., Chondroangiopathia Calcarea seu Punctata, Radiology, 1951, 57, 547.

8. Neale, A. V., Achondroplasia, in Modern Trends in Paediatrics, 1951, 480.

9. Potter, E. L., Pathology of the foetus and the newborn, Year Book Publishers, 1952, 442.

10. Potter, E. L. & Coverstone, V.A., Chondrodystrophy fetalis, Amer. J. Obst. & Gyn., 1948, 56, 790.

11. Shelling, D. H., Chondrodystrophy fetalis, in Brennemann's Practice of Pediatrics, W. F. Prior Co. Inc., 1948, Vol. 4, Chapter 28.

TES
oplasia

J. A.
, and
al re-

P. W.,
logists,

, Year

az, Vol.

ral Af-
51, 142-

Modern
ies, 381.
n, 1955.
hondro-
y, 1951,

Modern

and the

hondro-
948, 56,

talis, in
F. Prior